PSC Overview Series . . .
Nuclear Power Plant Decommissioning and Radioactive Waste Disposal

This Overview presents basic information about how nuclear power plant wastes are handled and what would happen to the waste if a nuclear plant shuts down. The PSC provides technical information in its Overview series as background material for government officials and the public who are interested in the status of Wisconsin's electric utility system.

Introduction

There are currently two operating nuclear power plants in Wisconsin. Of these, one recently obtained approval for dry storage capacity for its spent fuel, which is considered high-level radioactive waste. The two active plants have federal licenses to continue running until 2010 to 2013, depending on the reactor unit. By the year 2002, each will decide whether to apply for a license renewal to allow it to run as much as another 20 years or whether to shut down permanently at the end of its current license and be decommissioned. In addition to the two operating plants, there is one small unit which was permanently shut down in 1987 and is in storage waiting to be dismantled.

The PSC reviews the utility expenditures associated with nuclear waste storage and whether they would be in the ratepayers' interest. The Nuclear Regulatory Commission (NRC) reviews and approves safety features of storage systems.

This Overview provides basic information about low- and high-level radioactive wastes and nuclear decommissioning. It also provides some information about the status of the state's nuclear plants. Another PSC Overview addresses nuclear license renewal.

Low-level Radioactive Waste Disposal

Low-level radioactive waste disposal is an on-going routine activity at commercial disposal sites.

Low-level radioactive waste consists of material contaminated with radioactive elements from nuclear power plants, hospitals, medical and educational research institutions, biomedical companies, and other commercial activities that use radioactive materials. The waste is classified into three categories, described in Table 1.

Table 1 Categories of low-level radioactive waste

Category	Contents	Percent in 1995	Decay	Special Disposal Concerns
A	Mostly short half-life elements in protective clothing, paper, and lab trash.	97	Intruder to the disposal area would not receive excessive radiation exposure after 100 years.	No
B	Short and long half-life elements, in greater quantities.	2	Intruder would not receive excessive radiation after 100 years.	Must remain stable for 300 years. Usually stabilized in special cement.
C	Nuclear reactor shell, sealed sources, other high activity industrial waste.	1	Intruder would not receive excessive radiation exposure after 500 years.	Must remain stable for at least 300 years. Usually stabilized in special cement. Must be deeper disposal and protected from intruders for 500 years.

There are two existing commercial disposal sites for low-level radioactive waste: Hanford, Washington, which is open for waste from ten states in the Northwest and Rocky Mountain Low-Level Radioactive Waste Compacts; and Barnwell, South Carolina, which is open for waste from all states but North Carolina. A third disposal site, Envirocare at Clive, Utah, takes only very low radioactivity, large volume wastes from all states.

In 1970, the three states with operating disposal sites indicated that they did not want to be the only disposal sites forever. In 1980, Congress passed the Low Level Waste Policy Act, which made low-level radioactive waste disposal a state responsibility. Groups of states formed to develop regional disposal sites. Wisconsin became a member of the Midwest Compact, along with Minnesota, Iowa, Missouri, Indiana, and Ohio. The act was amended in 1985 to give states more time to build new disposal sites.

Potential new disposal sites have a variety of requirements. They should not, for instance, be where population growth or mineral exploration would affect the ability of the site to meet performance objectives. Sites must be free of flooding and far enough above the water table to prevent water intrusion into the disposal area. Siting should avoid geological risks such as volcanoes, earthquakes, landslides, slumps, or massive erosion. The title to a site would be transferred to a state or federal government agency that will restrict access to the site for 100 years after site closure. Environmental monitoring, periodic surveillance, and minor custodial care would occur during this period. Passive controls (markers, land records, soils, geology, containers) would need to meet performance objectives for the next 400 years. At the disposal site, waste might be put inside concrete cylinders or boxes to reduce site worker radiation exposure and to prevent future soil slumping if a container fails.

In the meantime, fees for disposal at the existing sites have increased substantially over the last ten years, and low-level radioactive waste generators have consequently learned how to reduce waste volumes significantly to save money. The Midwest Compact region generators have reduced volumes by 76 percent, using a variety of techniques, including:

- disposing of only contaminated material by separating it from non-contaminated material,
- compaction,
- incineration,
- cleaning with acid, or
- steam reforming.

As volumes have decreased, the economics of opening a new regional disposal site have become more questionable. The cost of identifying, constructing, licensing, and operating a site must be recovered from fees charged for disposal. However, volumes of waste are expected to increase when nuclear power plant decommissioning begins. So, for example, a disposal site in Illinois is now intended to start operation in 2012 rather than 2003 because disposal would cost too much for Illinois and Kentucky users before the higher volumes from plant decommissionings occur.

Other new disposal siting activities are on hold or being challenged. The economic advisability of licensing and operating a new disposal site in Nebraska has been questioned because low-level radioactive waste can be sent to existing sites for the next 20 years. Siting efforts in North Carolina, the Appalachian Compact, Connecticut, Massachusetts, and New York have all been redirected or halted in part because of questions about the need for new sites. The Barnwell site in South Carolina has 20 years of capacity left. The South Carolina legislature uses income from a surcharge on low-level radioactive waste disposed at Barnwell to provide $100 million for scholarships that would otherwise be supported by public taxes. The Envirocare facility in Utah is amending its license to take Class A waste with more radioactivity. The cost of a new site would be very high relative to the sites that exist. The estimated cost to find a site, license it, and open a new disposal facility is $105 to $216 million.

The Midwest Compact Commission decided to stop siting activities in Ohio because: (1) the costs of continuing were about to increase into millions of dollars per year; (2) disposal fees could be high; and (3) continued access to existing facilities for up to 20 years appeared likely. The Compact Commission also removed the host state designation from Ohio. The Compact Commission will continue to meet twice a year and, when circumstances change, may designate a host state again.

High-level Radioactive Waste Disposal—Spent Fuel

Reactor fuel is routinely used for three to four cycles of reactor operation, until it can no longer produce enough heat to generate electricity. Each cycle is 12 to 18 months long. In the reactor, heat energy is released when a neutron strikes and splits an atom of Uranium-235 (U-235). When an atom splits, energy is released in the form of heat, which boils water to produce electricity. The split fragments are radioactive forms of lighter elements. These radioactive elements will decay over time to non-radioactive elements.

When reactor fuel is removed from the reactor for the last time, it is stored in a "spent fuel" pool at the power plant for a minimum of five years. After five years, a typical spent fuel assembly is cool enough (in terms of both heat and radioactivity) to be put into dry storage, if necessary. The radioactivity has decreased to 0.34 percent of that when the fuel was discharged from the reactor.

After 100 years, the radioactivity of a typical spent fuel assembly will be 0.025 percent of the discharge level. Ultimately, the U.S. Department of Energy (DOE) will take possession of the spent fuel for disposal or intermediate storage.

The following sections discuss: (1) spent fuel storage in pools and dry casks at Wisconsin nuclear power plants; (2) transportation by the DOE to a permanent repository or interim storage facility; and (3) plans for evaluating Yucca Mountain as the permanent repository site.

Status of spent fuel storage at Wisconsin nuclear power plants

Wisconsin has three nuclear power plants. The Kewaunee Nuclear Power Plant, near Kewaunee, is jointly owned by three electric utilities: Wisconsin Public Service Corporation, Alliant-Wisconsin Power and Light Company, and Madison Gas and Electric Company. The Point Beach Nuclear Power Plant near Manitowoc is owned wholly by the Wisconsin Electric Power Company. The La Crosse Boiling Water Reactor in Genoa is owned by the Dairyland Power Cooperative and has been permanently shut down.

Kewaunee Nuclear Power Plant (KNPP)

The KNPP spent fuel pool was originally designed to serve two units. Thus, the spent fuel canal that connects the spent fuel pool to the existing reactor has a "dead end" section extending to the second reactor location. If spent fuel storage racks can be placed in this section, KNPP can store all its spent fuel in the pool until near the end of its license to operate from the NRC. KNPP's license expires on December 21, 2013.

Table 2 Number of spent fuel assemblies to be removed from the KNPP facility

	Spent fuel assemblies
KNPP operates through the end of license in 2013	1,180
KNPP operates through 2007	1,036
KNPP operates through 2002	860

Point Beach Nuclear Power Plant (PBNPP)

In 1995, the PSC authorized use of up to 12 "dry casks" for spent fuel storage and construction of concrete pads that could hold 48 casks. A supplemental analysis examined the effect of storage of 102 casks. Use of the spent fuel pool and 48 casks would allow PBNPP to operate until the end of license for each of its units. Construction of 102 casks would allow the utility to empty the spent fuel pool. PBNPP Unit 1's NRC license expires on October 10, 2010. Unit 2's license expires on March 8, 2013.

Table 3 Number of spent fuel assemblies to be removed from the PBNPP facility

	Spent fuel assemblies
PBNPP operates both units to the end of license (2010 and 2013)	2,471
PBNPP gains a 20-year license renewal (2030 and 2033)	3,591

LaCrosse Boiling Water Reactor

The LaCrosse Boiling Water Reactor was shut down in 1987 after operating for almost 20 years. Dairyland Power Cooperative is doing limited dismantlement of equipment and systems that are no longer needed. The plant is in safe storage (SAFESTOR). The spent fuel storage pool is inside the containment building. This plant cannot be decommissioned until all of the spent fuel has been removed from the pool.

Safety issues related to spent fuel pool storage

There are three major concerns with spent fuel storage in a pool: (1) degradation of boraflex in the spent fuel racks; (2) dropping a heavy load of fuel on a fuel rack as it is being moved over the spent fuel pool; and (3) the loss of water from the spent fuel pool to the extent that spent fuel is exposed.

Boraflex is boron in a silicon rubber matrix. Boraflex is attached to spent fuel racks to absorb neutrons that could cause a chain reaction, particularly in partly burned fuel. In fully burned fuel, there is less U-235 to react, and the atoms formed from earlier chain reactions absorb neutrons, preventing a chain reaction. Boraflex shrinks when in water and exposed to gamma radiation from spent fuel. Boron can wash out of the boraflex after long-term exposure to gamma radiation in the pool. Degradation can be detected as an increase in the concentration of silica in the pool water.

If heavy loads are moved across the top of the spent fuel pool, a dropped load could damage spent fuel, the pool structure, or the piping connected to the pool. Using fail-safe hooks, proper rigging, and avoiding unnecessary movement of heavy loads near the spent fuel pool can prevent such events.

In an operating plant, pool water can be lost if piping systems are improperly operated and siphon water from the pool. It can also be lost through the fuel transfer canal to the reactor refueling cavity, which is at a lower elevation than the spent fuel pool itself. In a closed plant, pipes can freeze and break if heating is not maintained. If pipes break at an elevation below the pool water level, siphoning could occur.

Spent fuel storage in dry casks

As spent fuel pools began to fill with spent fuel in the late 1970s, alternative storage technologies were sought. The goal was a modular system which might facilitate later transport to a permanent disposal site.

In 1982, the Nuclear Waste Policy Act was passed, directing the NRC to approve means of dry storage for the period before DOE begins taking spent fuel from reactors for permanent storage. The NRC developed procedures to review dry cask designs for safety. Once a dry cask has a general NRC license, a utility can use the cask at its reactor site without obtaining a site-specific NRC license for dry cask use. In Wisconsin, PSC approval is also required prior to construction of dry casks. The cask designs listed in the table below, have been licensed by NRC for use at a reactor site without further review of the cask design details. One of the licensing requirements is that the cask user must verify that the conditions at the cask site (wind speeds, temperatures, earthquake strength, precipitation) are bounded by the conditions used to design the cask and evaluated by the NRC when it issued a Certificate of Compliance for the cask. The utility must satisfy any conditions in the Certificate of Compliance. All utility actions related to use of the cask are subject to NRC inspection.

Table 4 Dry cask alternatives

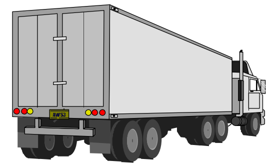
Cask Name	Manufacturer	Radiation (millirem/hr.) 3 feet from surface/public	Land Use (acres)
VSC-24	British Nuclear Fuels	15/0.01	5.5
Castor V/21	General Nuclear Systems, Inc.	50/0.03	5.5
NAC ST	NAC International	80/0.05	5.5
TN 24	Transnuclear	57/0.04	5.5
TN 32[1]	Transnuclear	56/0.03[1]	5.5
NUHOMS	Transnuclear West	48/0.03	5.5

[1] The TN 32 cask is currently in use under a site-specific license and is in the licensing process now for a Certificate of Compliance.

Casks are designed to withstand a tornado of greater intensity than the Barneveld tornado, missiles thrown into the cask by wind (such as an auto or an 8-inch diameter sphere weighing 275 pounds), earthquake forces of 0.25 g of side-to-side force and of 17 g vertical force without the cask sliding or tipping, a snow load of 100 pounds per square foot, and temperature extremes of -40° to 125°F.

Five cask manufacturers are proposing to build new casks for storage and rail transport. Westinghouse has sent an application for an NRC license for the Wessflex cask. Four other vendors are expected to apply to NRC for storage and transport casks: Holtech International, Transtor (previously Sierra Nuclear), Transnuclear West (previously NUHOMS), and National Assurance.

Spent fuel transportation



Spent fuel can be transported by truck or by train. It is transported in special casks that are designed to provide a barrier to radiation that prevents unsafe exposure of the driver or train crew and to the public along the route. The cask's shields block gamma rays and neutrons. The casks are also designed to transfer heat immediately to the outside.

The casks are also designed to prevent releasing radioactive material to the environment in accidents. They must withstand being dropped from 30 feet, landing on a vertical rod six inches in diameter, being exposed for 30 minutes to a 1,475°F fire, and being immersed under 50 feet of water for 8 hours and under 655 feet of water for 1 hour. A series of tests were conducted on several transport cask designs by Sandia National Laboratories, using full size casks. The tests involved:

- A tractor-trailer rig carrying a cask and crashing into a concrete barrier at 60 and 80 mph.
- A 120-ton locomotive going 80 mph and colliding with a cask on a truck at a crossing.
- A high-speed impact followed by a 30 minute diesel fire.

None of the tested spent fuel casks were damaged enough to release radioactivity.

Both the NRC and the U.S. Department of Transportation (USDOT) regulate the shipment of spent nuclear fuel. The NRC regulates the safety of the transport cask in which the fuel is shipped. The NRC licenses the casks and inspects cask fabrication plants. Each license lasts five years and can be renewed. The USDOT covers route selection, vehicle condition, vehicle labeling, driver training, and package marking. The NRC approves transportation routes and requires certain protection measures that include notifying the NRC in advance of shipment. State governors, or their designees, are also notified of each shipment, at least four days before the shipment. The DOE has proposed satellite tracking of shipments.

The USDOT has identified preferred routes for truck transport of spent fuel and has identified guidelines for states and tribes to use in selecting alternative routes. The preferred routes are interstate highways between centers of population, unless the affected state specifies a different route. The state determines the route around major cities.

Train routes are determined by the shipper and the railroad. Track conditions are considered when picking a route. If a dedicated train is used, the train stops only for fuel, to change crews, and sometimes to change or add locomotives, as it would when approaching mountains.

The USDOT also administers grants for planning and emergency training on transport of hazardous materials, including spent nuclear fuel. The DOE plans to make additional training money available to states, counties, and tribes three to five years before shipments to a repository or interim storage site would begin.

Over the last 25 years over 2,500 shipments of spent fuel have been made, about 2,353 by truck and 293 by rail. During this time, seven accidents occurred. Four were on rail shipments and three were on trucks. None resulted in a radioactive release. In one case a cask was thrown more than 100 feet. The package suffered minor damage. In the other accidents, no cask damage occurred.

Spent fuel permanent repository

The only site that is being investigated as a permanent repository is Yucca Mountain in southern Nevada, about 100 miles northwest of Las Vegas. The repository would ultimately hold spent fuel from utility and research reactors and waste from military reactors and manufacture of nuclear weapons. About 33,000 tons of spent fuel has accumulated at the nation's utility reactors to date. If all reactors were to operate for 40 years, the amount would increase to 92,000 tons. The amount of government spent fuel and high level waste is expected to be about 3,066 tons.

Under the Nuclear Waste Policy Act of 1982 as amended in 1987, a contract was created between the electric utilities and the federal government. Electric utilities would pay into a nuclear waste fund for spent fuel disposal and storage, in advance, and the federal government would develop a permanent repository to receive spent fuel from utilities. The DOE was to begin taking spent fuel from utilities on January 31, 1998. So far, electric utilities have paid over $12 billion dollars to the nuclear waste fund at a rate of 1 mill/kWh generated by nuclear power plants. The Wisconsin share of the payments was $264.1 million through June 30, 1997. Interest on the payments has added $102.1 million to the Wisconsin share of the fund total. The utilities' payments were intended for studying, licensing, constructing, and operating a repository for spent nuclear fuel. Congress has released about half of the funds to DOE. The rest of the fund offsets the federal deficit.

When the January 31, 1998, deadline passed, a combination of utilities and state agencies sued the DOE, requesting the court to order the DOE to begin taking spent fuel. The court ordered the DOE to begin performing the actions required by terms of the act, that is, to begin taking the spent fuel. The DOE has not yet begun taking spent fuel from utilities. It has taken, and is storing, spent fuel from Navy vessels and foreign research reactors where the U.S. government supplied the fuel.

Several aspects of the Yucca Mountain repository site (water movement, effects of heat on water movement, and chemistry, for example) are still being studied. A viability assessment that will identify where more work is needed is expected in the fall of 1998 (see below). A performance assessment would be part of a license application that the DOE currently expects to file in 2002.

Responsibilities for spent fuel disposal

The DOE is responsible for developing a system to manage the disposal of high-level radioactive waste and spent nuclear fuel. According to 10 CFR Part 960 of the federal code, the DOE must develop a repository for high-level waste and spent nuclear fuel.

The U.S. Environmental Protection Agency (EPA) contracted with the National Academy of Sciences (NAS) to advise them on the appropriate technical basis for public health and safety standards at the Yucca Mountain repository. NAS issued this study, entitled "Technical Bases for Yucca Mountain Standards," on August 1, 1995.

According to 10 CFR Part 197, the EPA is responsible for developing appropriate radiation protection standards for management and disposal of high-level waste and spent fuel. It was directed to issue its standards, based in part of the NAS study, a year after the study was published. The standards are now expected to be available in 1998. The EPA must also review all of the DOE's environmental impact statements.

The NRC must conform its technical criteria in 10 CFR Part 60 to the new EPA standards or issue new standards within a year of the publication of the revised EPA standards. The NRC is the organization that will issue a license for a spent fuel repository and ensure that the DOE meets the EPA standards. The NRC must find that public health and safety has been adequately protected. The regulations in 10 CFR Part 60 govern pre-licensing activities, authorization to begin construction of a facility, a license to receive and place spent fuel and high-level waste in a facility, and a license to close a facility. The NRC would also license any interim storage facility for spent fuel, and licenses spent fuel transportation casks.

The U.S. General Accounting Office must audit the DOE's programs and progress in licensing a high-level waste and spent fuel repository, and must publish the audit findings.

The Nuclear Waste Technical Review Board was created to advise Congress and the Secretary of Energy on issues related to high-level waste and spent fuel disposal. It is independent of the DOE and other governmental agencies.

Prior to acceptance of spent fuel by DOE, each utility that operates a nuclear plant is responsible for spent fuel it produces. Each utility must store the fuel in a spent fuel pool and/or NRC-approved dry casks. The utility ratepayers pay for this storage.

Nuclear Power Plant Decommissioning

The nuclear plant's options

When a nuclear power plant becomes uneconomic to operate or reaches the end of its 40-year license with the NRC, the plant either: (1) begins "decommissioning;" and is dismantled; (2) is put into storage, called SAFSTOR, for decommissioning later; or (3) applies to the NRC for a 20-year extension of the license. The NRC states that decommissioning must be completed within 60 years of when the nuclear power plant shuts down.

In deferred decommissioning, or SAFSTOR, the facility is kept in a safe, nonoperating, environmentally sound condition while the radiation decays until it is ready to be dismantled. SAFSTOR is most commonly used when one unit at a multi-unit site shuts down. The advantages of SAFSTOR are that much of the radioactivity has decayed so that occupational radiation exposures are much less than with immediate decommissioning. The disadvantages of SAFSTOR are that equipment needed during decommissioning may degrade in storage, costs of low level radioactive waste disposal will be higher, and insurance premiums must be paid for a longer time.

The advantages of immediate dismantlement are that experienced plant workers participate in the decommissioning, costs of low level radioactive waste disposal are known, equipment needed in decommissioning is in good shape, and insurance premiums are paid for a relatively short time.

The status of decommissioning in the U.S. and Wisconsin

NRC has identified several decommissioning issues that will need rulemaking. Three topics are in or through this process now: decommissioning, financial assurance, and radiation site release criteria. Four upcoming additional topics are: decommissioning costs, required amount of insurance coverage for permanently shutdown reactors, physical protection for storage of spent fuel at permanently shutdown reactors, and operators and plant staffing for decommissioning reactors.

The Commission reviews the expected cost of decommissioning every four years to determine whether the amount of money collected from ratepayers to pay for decommissioning should be changed. The review includes a formal hearing. Funds collected in rates for decommissioning are set aside in a decommissioning account. Decommissioning funds can be invested in common stocks and investment grade fixed income securities. However, no more than 45 percent of the decommissioning funds may be invested in common stocks, and no more than 5 percent of the funds may be invested in a single company.

The NRC has approved six decommissioning plans since 1992. As of September 1996, 17 power reactors were in various stages of decommissioning. A public meeting was held in May 1998 on the decommissioning plan for the La Crosse Boiling Water Reactor in Genoa. The NRC approved a

SAFSTOR decommissioning plan for this plant on August 7, 1991. This plant was shut down on April 30, 1987.

The two operating Wisconsin nuclear plants, KNPP and PBNPP, could each apply for a 20-year NRC license extension. The KNPP NRC license ends in 2013. The PBNPP NRC licenses expire in 2010 and 2013.

The decommissioning process

The NRC must be notified within 30 days after the unit is permanently shut down. Another written notification must be submitted when the spent nuclear fuel is permanently removed from the reactor. Within two years of the second notification, the licensee must submit, to the NRC, a report describing the projected decommissioning activities, plus a schedule and an estimate of the costs. The NRC reviews the report, publishes a notice of its receipt, makes the report available to the public, performs further environmental review of the decommissioning if necessary, and holds a public meeting near the plant.

Ninety days after NRC receives the report, decommissioning may begin. Without specific NRC approval, decommissioning activities are limited to those that do not: 1) foreclose the release of the site for unrestricted use, 2) result in excessive use of the decommissioning funds, or 3) cause environmental impacts that have not already been subject to review. If any of these effects might occur, the plant owner must submit a license amendment to the NRC.

Decommissioning activities include:

- Decontaminating large metal parts (steam generators or large pipes, for example).
- Removing insulation around piping.
- Removing the surface one or two inches of concrete to remove the radioactive contaminated portion.
- Dismantling the plant.
- Shipping uncontaminated pieces to scrap metal users or landfills.
- Shipping radioactive parts to a low-level radioactive waste disposal site.

Some parts (internal parts) are too radioactive for disposal in a low-level radioactive waste disposal site. These parts and the spent nuclear fuel must be sent to a federal high-level nuclear waste disposal facility, whenever such a site opens.

Decontaminating metal parts reduces the cost of decommissioning. Metal is decontaminated by repeated washing with a dilute acid (nitric or formic acid). The acid dissolves the radioactive contamination, and also some of the base metal to release radioactive contamination in microscopic fissures. The radioactive compounds and metal are removed from the acid solution in ion exchange columns. The water is removed from the resins in those columns and the radioactive material is packed into a “High Integrity Container” and shipped to a low-level radioactive waste disposal site. Use of this technique should substantially reduce the volume of material that is sent to a low-level radioactive waste site.

Helpful Nuclear Power Definitions

Ionizing radiation

Any radiation that will strip or displace electrons from atoms and produce ions. Types of ionizing radiation include alpha radiation, beta radiation, gamma radiation, and X-rays. Background levels of radiation in Wisconsin are 300 millirem from solar and cosmic radiation, natural radioactive material in surrounding rocks and soil, and in concrete, bricks, and the human body.

Radioactivity

Spontaneous emission of radiation from the nucleus of an unstable atom. The intensity of activity in a sample of material is measured in curies.

Alpha particle

Positively charged particle emitted by certain radioactive material, made up of two protons and two neutrons. It does not penetrate clothing or skin.

Beta particle

Negatively charged particle emitted in the radioactive decay of certain radioactive elements. A beta particle has mass and charge equal to that of an electron. It has a short range in air and a low ability to penetrate materials.

Gamma radiation

Short-wavelength radiation emitted by the radioactive decay of certain radioactive elements. Gamma rays are highly penetrating, similar to X-rays.

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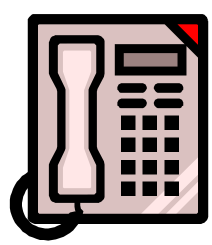

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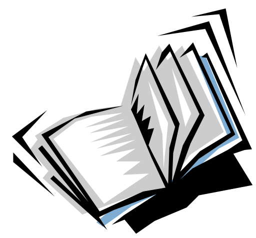

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